PERIODICITY IN DICTYOTA AT NAPLES

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(WITH ONE FIGURE)

Periodicity in the production of the sexual cells of *Dictyota dichotoma* has been described by Williams (**8**) for Bangor, Wales, and Plymouth, and by Hoyt (**2**) for Beaufort, North Carolina. At Bangor the sexual products are liberated at fortnightly intervals, the rudiments of sexual organs appearing a few tides before the least neap, and the mature gametes being liberated 3–5 tides after the greatest spring. In October, however, the time relations are reversed. At Plymouth the crops are later, as well as slower in maturing, than at Bangor, liberation occurring 7–12 tides after the greatest spring. At Beaufort only one crop a month is produced, the initiation of rudiments occurring the day before, or the day of, and liberation taking place six days after, the greatest spring tide.

These striking differences in the behavior of what is pronounced to be the same species in different localities make it desirable that careful observations be recorded for this form in other regions than those mentioned, and especially in those regions where the tidal relations are different. Williams surmises that "the periodicity of the sexual cells is an hereditary character, and consequently may be expected to manifest itself in seas and habitats where there are no tides." Oltmans (**5**, pp. 487, 488) states: "Williams findet einen Zuzammenhang der Entwickelung und Befruchtung und mit den bekanntlich in Abständen von 14 Tagen auftretenden 'Spring- und Nipptiden.' Da solche im Mittelmeer fehlen, werden erneute Untersuchungen hier die Dinge zu klären haben."

With these facts in mind, I took occasion, during March and April 1908, to make daily notes on the condition of the sexual plants of *Dictyota* at Naples.[1] The results of these observations are here presented.

[1] I take this opportunity of expressing my thanks to the directors of the Smithsonian Institution for the privilege of occupying a table at the Zoological Station in Naples, and to Dr. R. Dohrn and Dr. Lo Bianco for their cordial cooperation during my stay in Naples.

The range of the tides at Naples is very much less than at either Beaufort or Bangor, though it cannot be said that tides are wholly lacking at this point. The daily readings of the tide gauge near Naples, furnished by the Italian government, agree closely with the tides predicted by the U.S. Coast and Geodetic Survey. Extraordinary conditions of wind and weather, however, may affect the range of the tides very appreciably. For the period studied, the maximum daily range of the tides was 2.1 feet, the minimum 0.4, the average 1.0. The water level varied from 0.7 feet below to 1.5 feet above mean low water of spring tides. The following table gives an idea of the relative ranges of the tides at Bangor, Beaufort, and Naples.

TABLE I

	Average range	Difference in height of low water at spring and neap tides
Bangor	17.9 feet	5.7 feet
Beaufort	2.8	0.5
Naples	1.0	0.25

The sexual cells of *Dictyota* were found to be produced at regular intervals, the time of initiation of the rudiments and liberation of the mature gametes bearing a definite relation to the periodic changes in the tides. The crops are borne, as at Bangor, at fortnightly intervals. Initiation of the rudiments occurs on the same day as general liberation of the mature gametes, this being two or three days after the least neap tide. The number of days required for the development of a single crop is approximately sixteen. The development of the sori is fairly uniform, not being accelerated at the time of the spring tides.

A comparison of the facts of periodicity in *Dictyota* at Bangor, Beaufort, and Naples is given in the following tables.

The accompanying chart (fig. 1) gives in graphical form the record of one crop from initiation to liberation, showing the relations between the tidal changes and the fructification of *Dictyota*. The chart should be compared with the charts given by HOYT (**2**, pp. 386, 387) in order to compare the behavior of *Dictyota* at various localities.

At any given time all the individual plants, collected at various points from Capo Miseno to Santa Lucia, are at approximately the same stage of development. There are noticeable differences, however, as for instance in the plants collected on April 10. According to the chart, this date shows the beginning of liberation of gametes,

TABLE II

	Initiation	Liberation	Time of development
Bangor	A few days before the the least neap	3–5 tides after greatest spring	12–17 days
Beaufort......	Day before or day of greatest spring	6 days after greatest spring	8–9 days
Naples........	2–3 days after least neap	2–3 days after least neap	16 days

TABLE III

HISTORY OF A SINGLE CROP

Day	Beaufort	Bangor	Naples
1............	Undivided rudiments	Undivided rudiments	Undivided rudiments
3............	8–16 cells in surface view of antheridia	Undivided rudiments	Undivided rudiments or 2–4 cells
4............	32–64 cells	Undivided rudiments	2–4 cells
5............	64 cells	Undivided rudiments	2–4 cells
6............	General liberation		2–4 cells
7............	Belated sori	2–4 cells	4 cells
8............			4–8 cells
9............			8–16 cells
10............		Many sori. 64 cells	16 cells
11............			16–32 cells
12............		General liberation	32–64 cells
13............		Belated sori	64 cells
15............			General liberation
16............			Belated sori

and also the beginning of initiation of rudiments. As a matter of fact, the numerous individuals examined on this day showed considerable differences among themselves. The male plants may be grouped in the following categories: (1) no antheridia empty, new crop not visible; (2) none empty, new crop inconspicuous; (3) very few antheridia empty, new crop conspicuous; (4) antheridia empty near base of plant, not empty near apex, new crop barely visible; (5) antheridia as in no. 4, new crop conspicuous, some of the rudiments 4-celled in surface view; (6) antheridia nearly all empty, new crop

barely visible; (7) antheridia all empty, new crop showing 4 cells. The majority of plants collected on this day were in the fourth or fifth stage.

The tendency toward periodicity in the production of sexual cells is probably a hereditary character. That periodicity is not a series of simple responses to successive stimuli is shown by the observation of WILLIAMS that individuals removed from the influence of the tides continue to show the usual periodicity, and by HOYT's statement that individuals produced by vegetative multiplication

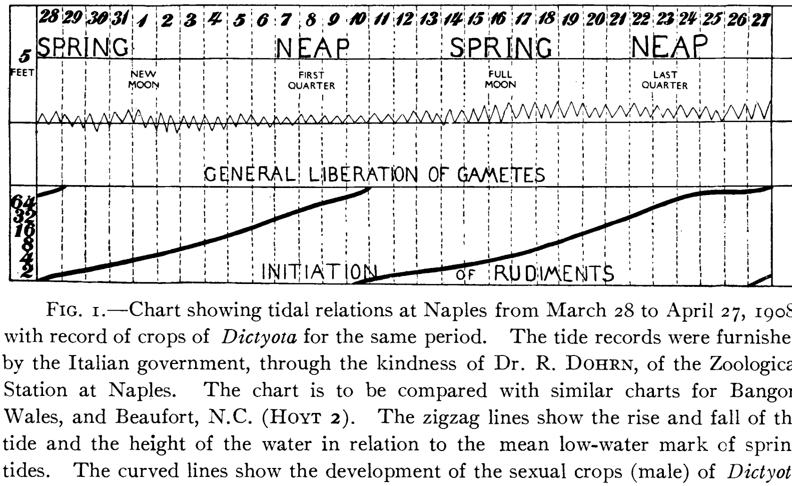

FIG. 1.—Chart showing tidal relations at Naples from March 28 to April 27, 1908, with record of crops of *Dictyota* for the same period. The tide records were furnished by the Italian government, through the kindness of Dr. R. DOHRN, of the Zoological Station at Naples. The chart is to be compared with similar charts for Bangor, Wales, and Beaufort, N.C. (HOYT 2). The zigzag lines show the rise and fall of the tide and the height of the water in relation to the mean low-water mark of spring tides. The curved lines show the development of the sexual crops (male) of *Dictyota* for the respective periods with their relations to the tides. The numbers opposite the crop curves indicate the number of cells seen in the surface view of each antheridium.

and never subjected to the influence of the tides show approximately the same periodicity as those in their natural habitat. The former observation was confirmed by me at Naples, and goes to show that the habit of periodical reproduction is fairly well fixed. The habit, however, must have had its origin in response to external conditions, and it is a matter of considerable interest to ascertain, if possible, what factor or factors gave rise to the periodicity. The only suggestion made thus far is that of WILLIAMS that the effective factor is the increased illumination during low water of spring tides, a view from which HOYT dissents.

WILLIAMS' hypothesis seems inadequate to explain the periodicity at Naples. *Dictyota* flourishes there at a depth of many feet below

the surface, and the difference between the height of low water at spring and neap tides is only 0.25 feet. This slight difference can hardly cause any considerable variation in the total illumination of the plants under consideration, not as much as is caused by alternating cloudy and sunny days. It is interesting to note, however, that both initiation and liberation occur at Naples on the day that low water occurs at or nearest midday. Thus low water at midday occurred at Naples on March 29, April 10, and April 27, 1908, the days when initiation and liberation were found to occur. Whether this is more than a coincidence is still to be seen, but the fact remains that the critical points in the sexual life of *Dictyota* coincide exactly with the periods of maximum intensity of illumination.

If one considers the behavior of *Dictyota* at Naples alone, it seems a fairly satisfactory hypothesis that the effective factor in producing periodicity is the stimulus of the maximum intensity of light. When one comes to apply this hypothesis to the other regions where *Dictyota* has been studied from this standpoint, it becomes evident that, if true at all, the hypothesis is modified by other factors. At Beaufort, for instance, low water at midday occurs two days before new and full moon, while initiation occurs on the day before or the day of the greatest spring tide. At Bangor, on the other hand, low water at midday occurs about five days before new or full moon, and initiation takes place one to two days before the least neaps. At Plymouth low water of the greatest spring tides occurs at midday, and here the times of initiation and liberation coincide more nearly with the periods of neap tides. It is obvious, then, that the simple explanation that might suffice for Naples is not sufficient for other localities, and that the operative factor or factors must be sought by further investigation.

It seems possible that *Dictyota*, in adapting itself to differing conditions at various localities, has acquired its habit of periodicity in response to different factors. That a similar stage in the reproduction of other algae may be induced by different stimuli has been shown by FREUND (1) to be the case in *Oedogonium* and *Haematococcus*. In these forms the external conditions leading to the formation of zoospores differ according to the condition of the individual plants. For instance, cysts of *Haematococcus* form zoospores

(1) when transferred from foul to distilled water, (2) when brought from darkness into light, (3) when water is replaced by sugar solution. KLEBS's investigations (**3**) illustrate the same point for other algae and fungi. Since the fructification of other forms may be induced by different factors, it is possible that the same may be true for *Dictyota* in various situations, and that the factors concerned in inducing periodicity may vary with the locality.

Other organisms, both animals and plants, show a periodicity in the release of sexual cells comparable to that of *Dictyota*. In *Amphitrite ornata*, an annelid worm, "practically all sexual products are deposited within three days of spring tides" (SCOTT **6**, p. 332). KUCKUCK finds (**4**) in *Nemoderma tingitana* that the gametes are released at times of neap tides. TAHARA shows (**7**) that the oospheres of *Sargassum enerve* are released at fortnightly intervals at about the time of new and full moon. Other species of *Sargassum* are said by TAHARA to show a similar periodicity, in which liberation occurs at various intervals after the greatest spring tides.

It is obvious, therefore, that periodicity in the release of sexual cells is a widespread phenomenon, probably to be attributed to various factors in different species, and perhaps to more than one factor in the same species in different localities.

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